Experimental Report

March-April 2023

Running Cost Test

Any questions?
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Introduction:

The aim of this experiment is to compare the trust electric radiator against its competitors in terms of running cost and how it heats up a space by recording temperature and humidity. The purpose of this experiment is to identify the most efficient electric radiator in terms of running costs and its ability to provide comfortable living conditions.

Background Study:

Importance of analysing electricity consumption in radiators:

According to Office for National Statistics report on the latest data and trends about how changes in energy prices is affecting the cost of living across the U.K.

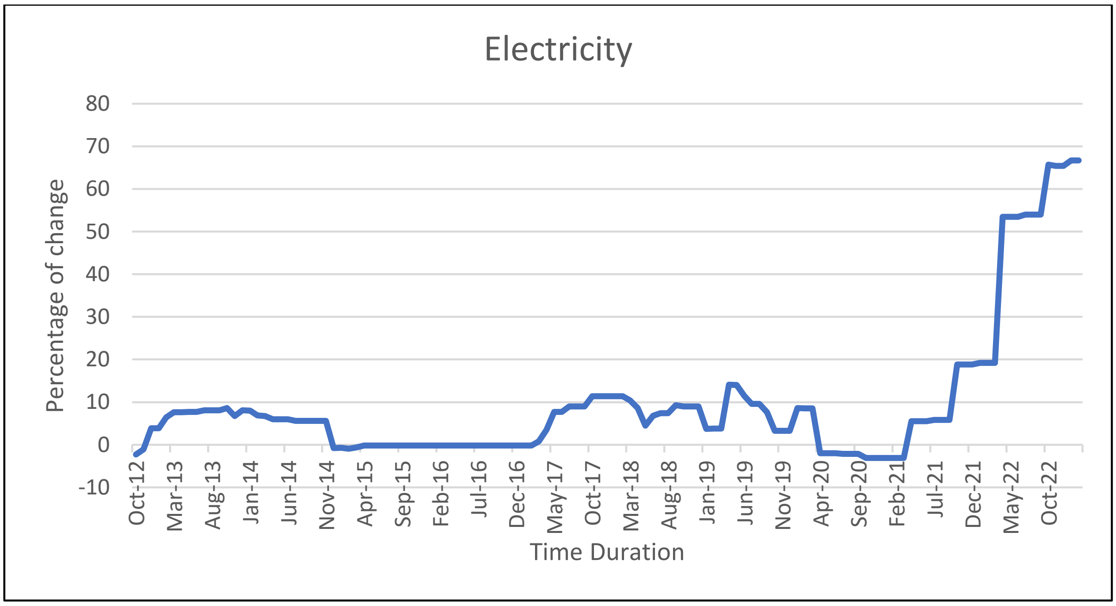


Figure 1 Electricity annual CPIH inflation rates, UK (Office for National Statistics , 2023)

According to the figure 1 which is based on the data published by Office for National Statistics, electricity prices in the UK rose by 66.7% in the last 12 months to February 2023, and were some of the main drivers of the annual inflation rate. Between March 22 and April 2, 2023, a significant majority of adults (73%) reported that an increase in their gas or electricity bills had resulted in a rise in their overall cost of living. Additionally, nearly half (49%) of those who pay energy bills found it challenging to afford them due to the escalating energy prices. Consequently, the impact of these rising costs has prompted individuals to alter their behavior during the winter season.

During the period of February 15 to 26, 2023, approximately one-fifth (20%) of adults residing in Great Britain reported experiencing occasional or infrequent comfort in keeping their homes warm. This percentage was lower compared to the months of November and December 2022 (24%), which could be attributed to the relatively mild weather during the recent survey period.

The groups identified as most vulnerable to difficulties in maintaining warmth at home in February 2023 were individuals exhibiting moderate-to-severe symptoms of depression (47%), those residing in the most deprived areas of England (37%), and those who were classified as "economically inactive" and not yet retired (37%).

Looking at the difficulties people are facing due to steep increase in energy prices, highlights the importance to understand how much the radiators are costing to operate as it would be worth knowing where people might be able to make savings.

How much does an appliance cost to run?

The amount it costs to run appliances depends on three things:

- The rating (watts)
- The price you are charged per unit of energy (your energy tariff)
- How long the appliance is running for?

The electricity used by domestic appliances varies between makes and models. If you know the power rating of the appliance and the electricity unit rate of your supplier, it's possible to use the following equation to calculate the running costs of your appliance.

Appliance running cost (p/hr) = Power rating (W) x Electricity unit rate (p/kWh) ÷ 1000

The power consumption of some appliances like washing machines and tumble driers varies over the time they're used. For example, the washing cycle will use more electricity than the spin cycle. We know cycle lengths will vary so the costs will vary as well. ECO settings tend to wash at a lower temperature so less energy needed to heat the water. (National Energy Action, 2022)

What if the radiator behaves same way the washing machine consumes electricity? The owners of dwelling won't be able to know exactly how the energy is getting consumed. For this to understand let's look at power ratings and its importance.

What is power rating?

Power rating describes the total electrical power an appliance requires for its normal operation. It defines how much energy is being transferred from the grid to power the instrument or device. The power rating also indicates the maximum power at which the unit can safely operate. For example, most phone chargers have a power rating ranging between 5 and 25 watts. That means the devices draw a maximum power of 25 watts or 25 joules-per-second from the mains electricity supply. (Electric Rate, 2023)

Why is Power Rating Important?

The power rating indicates the maximum power input that can flow through a given piece of electrical equipment. Exceeding that capacity increases the chances that the machine or equipment will break down since it is not equipped to operate beyond the given parameters. Also, power rating of an electrical appliance is an important specification that helps users determine the energy requirements and performance capabilities of the appliance.

Understanding the power rating of an electrical appliance is crucial for selecting the appropriate appliance for a particular purpose, ensuring safe and efficient operation, and managing energy consumption.

There are tolerance standards as guidelines or specifications that determine the acceptable deviation or variation from the stated power rating of an electrical appliance. These standards are typically set by regulatory organizations or industry associations to ensure consistency and safety in electrical appliances. Tolerance standards for power rating are important to ensure that appliances operate within safe limits, avoiding overloading or damaging the electrical system. For example, if an appliance has a power rating of 1000W with a tolerance of +/- 5%, it means that the appliance's actual power consumption or output can vary by up to 5% from the stated power rating, ranging from 950W to 1050W. Adhering to tolerance standards is essential to ensure that electrical appliances are manufactured, tested, and used in compliance with safety regulations, and to prevent potential risks such as electrical hazards, equipment failures, or inefficient energy consumption.

The British Standards Institution (BSI) is a recognized authority that establishes and maintains standards for various industries, including electrical appliances. In the UK, electrical appliances are subject to standards such as BS EN (British Standard European Norm) and BS IEC (British Standard International Electrotechnical Commission) which specify the requirements for power rating and tolerance.

For example, the BS EN 60335 series of standards cover the safety requirements for household and similar electrical appliances, including their power rating and tolerance. These standards provide guidelines on the maximum power consumption, output capacity, and acceptable tolerance limits for various types of electrical appliances, such as refrigerators, washing machines, heaters, and more. The tolerance limits specified in these standards ensure that appliances operate safely and efficiently within acceptable power consumption levels.

Additionally, the UK government also sets regulations and guidelines through organizations like the Office for Product Safety and Standards (OPSS) and the Health and Safety Executive (HSE) to ensure that electrical appliances meet safety requirements, including power rating and tolerance, to protect consumers and prevent potential risks associated with electrical appliances. Adhering to these standards and regulations is essential for manufacturers, retailers, and consumers to ensure the safe and efficient use of electrical appliances in the UK.

1kW in versus 1kW out

Electric radiators are an essential part of heating systems in many homes and commercial spaces. They are designed to convert electrical energy into heat energy, which is then transferred to the surrounding space to warm it up. However, the effectiveness of a radiator in transferring heat to the room can vary, despite having the same 1kW rating.

The perception among customers and which the many manufacturers of radiators don’t want to clear is that a radiator for example with a 1 kW rating will convert that energy into heat to warm up a room, meaning 100% efficiency. This aligns with the scientific principle that energy cannot be destroyed but can be converted from one form to another. This understanding forms the basis of a radiator's efficiency, which refers to how well it converts energy into heat. However, an equally important concept is effectiveness, which pertains to how effectively the radiator transfers heat to the room.

The effectiveness of a radiator in heating a room efficiently depends on several factors, including design, material build, and other influencing factors.

Importance of design in radiator effectiveness

The design of a radiator plays a crucial role in determining its effectiveness in transferring heat to the room. A well-designed radiator with features such as a larger surface area, optimized fin spacing, and efficient heat conduction can significantly enhance its effectiveness. Radiators with proper design considerations can transfer heat more efficiently, ensuring that more of the energy input is utilized for heating the room quickly, rather than taking long time.

Role of material builds in radiator effectiveness

The material build of a radiator also impacts its effectiveness in transferring heat to the room. Radiators can be made from various materials, including steel, aluminium, cast iron. Inside the casing can be different types of storage elements such as stone, concrete etc. Each material has its unique properties that affect the efficiency and effectiveness of heat transfer. For example, aluminium radiators are known for their high thermal conductivity, which allows them to heat up quickly and transfer heat quickly. On the other hand, cast iron radiators are known for their ability to retain heat for longer periods, thus taking much longer time to transfer that heat to room. Thus, the choice of material build for a radiator can greatly influence its effectiveness in heating a room.

Methodology:

To conduct this experiment, we selected four competitive samples for comparison against the Trust Neos 1.2kW electric radiator. The competitors samples included:

- A leading UK-German Electric Radiator (1.2kW),
- German Electric Radiator (1.1kW),
- Oil Filled Panel Radiators (1 kW), and
- Electric Panel Heater (1.2 kW).

All of these radiators were installed in a test room at the Trust facility in Leeds, UK. This installation ensures that the room size and insulation levels remain consistent across all tests. It is important to note that the Trust lab simulates typical room conditions, akin to those found in a residential setting. This should not be conflated with a climatic room, where environmental conditions are strictly controlled. This approach allows for the consideration of external factors that may influence the normal operation of the device.

The important part of the test setup involves measuring energy consumption using an Owl Intuition device. The Owl Intuition is a device that can monitor energy consumption and transmit the data to a network and further to cloud storage. This data can then be analysed using an online interface. The Owl Intuition device measures energy consumption by monitoring the electrical current flowing through the main power line that supplies power to the equipment. This data can be used to track energy usage and identify areas where energy is being wasted or used inefficiently.

The second part of the test setup involves measuring temperature at different levels using thermocouples. A thermocouple is a type of temperature sensor that consists of two different metals connected at one end. When the temperature changes, the two metals generate a small electrical signal that can be measured and recorded. In this setup, three thermocouples are used to measure temperature at different levels: top, mid, and bottom. This allows to analyse temperature at head height, waist height, and knee height. By measuring temperature at different levels, it can be determined if convection is taking place. Convection is the transfer of heat through the movement of fluids, such as air or water. If convection is taking place, the temperature at different levels should be roughly in same range. If there is no convection, the temperature difference between levels will vary by high number.

To record the temperature data from the thermocouples, PicoLog data loggers are used. A data logger is a device that can record data over time. The data is stored on a computer drive and later analysed.

The third part of the test setup involves recording the humidity. Humidity is the amount of moisture in the air, and it can affect how comfortable people feel in a building.

To record the humidity, a humidity sensor is used. The sensor measures the amount of moisture in the air and provides a reading in percent relative humidity (%RH). In this case, it is done by recording the humidity at the start and end of the test, which can help to determine how the humidity level changed during the test and how it affected the indoor environment.

In addition to recording the humidity, the outside temperature is also recorded. This is important because the temperature outside can affect the temperature inside the building. For example, if it is very cold outside, the building may lose heat more quickly, causing the indoor temperature to drop. By recording the outside temperature, can take this into account when analysing the data.

Overall, by recording energy consumption, temperature, humidity, and outside temperature, the study can gain a comprehensive understanding of how the radiator is performing and where improvements can be made to reduce energy usage and improve comfort for the occupants.
To maintain uniformity, a common thermostat have been used and set to 20 degrees Celsius for all cases. Additionally, a thermocouple has been placed near each thermostat to record the temperature in its immediate vicinity and check the effectiveness of the thermostat.

Results /Data:

Trust Electric radiator

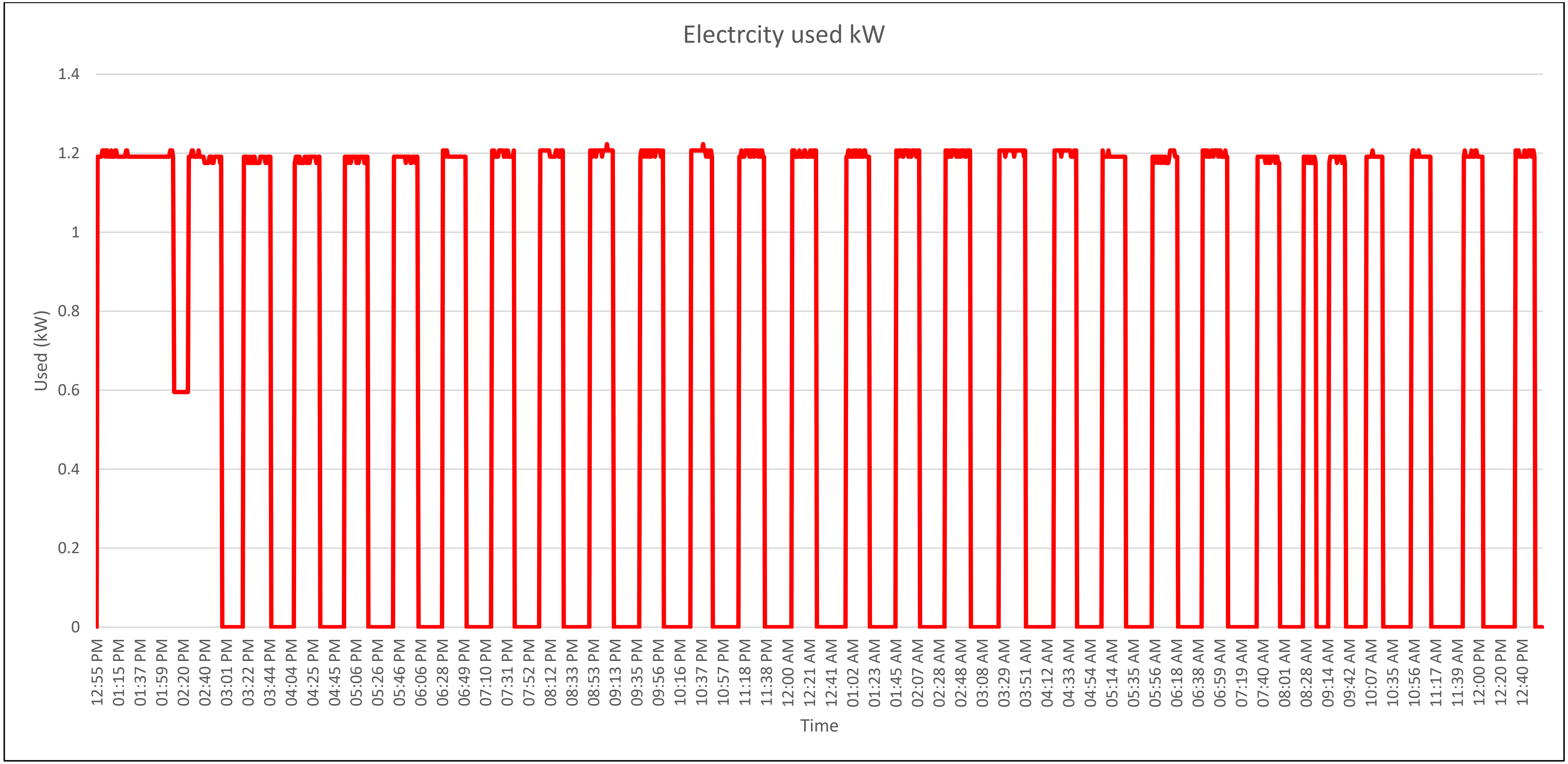


Figure 2 Electricity consumption -Trust electric radiator

Temperature:

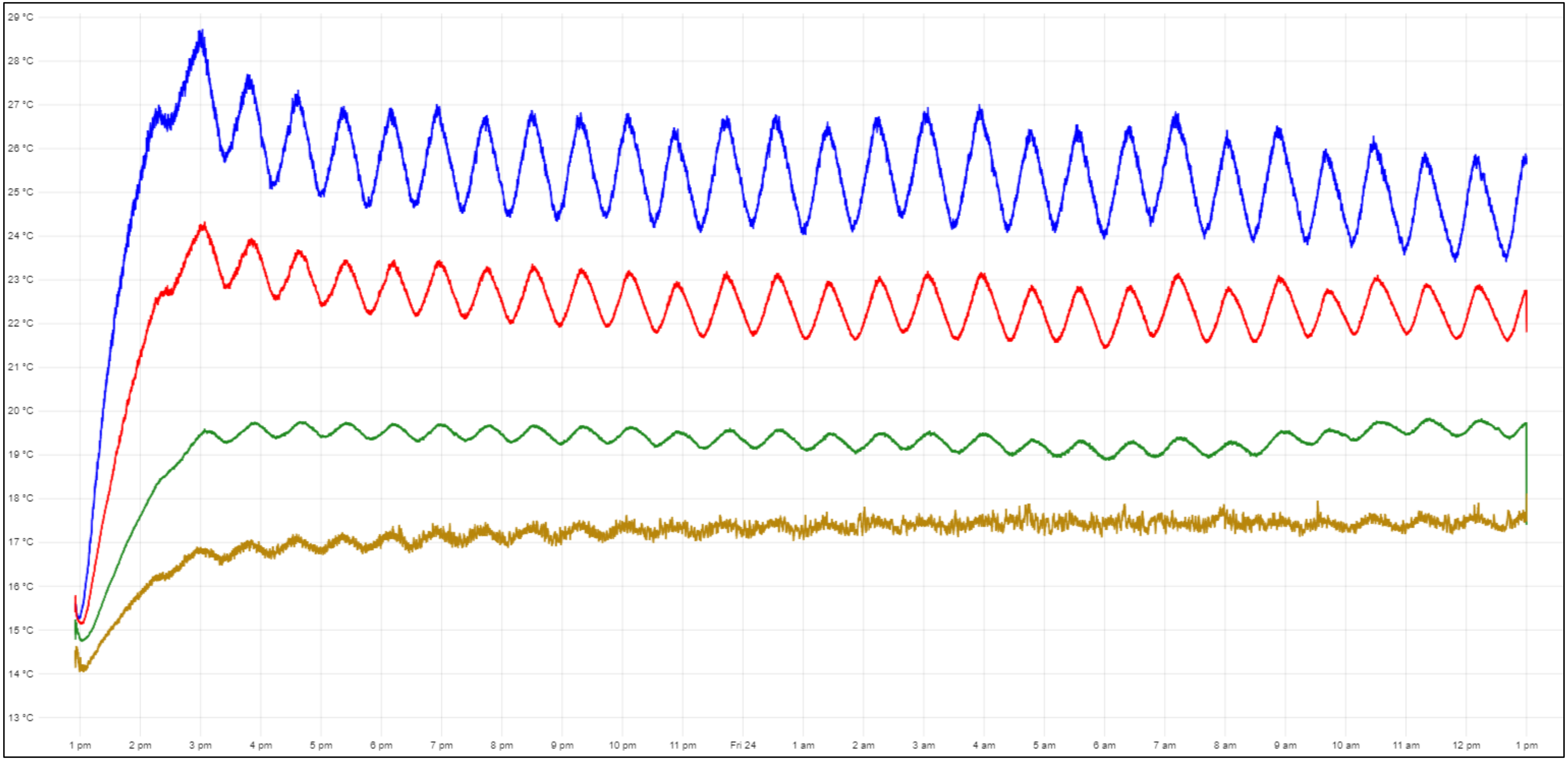


Figure 3 Room temperature -Trust electric heating

German Electric Radiator:

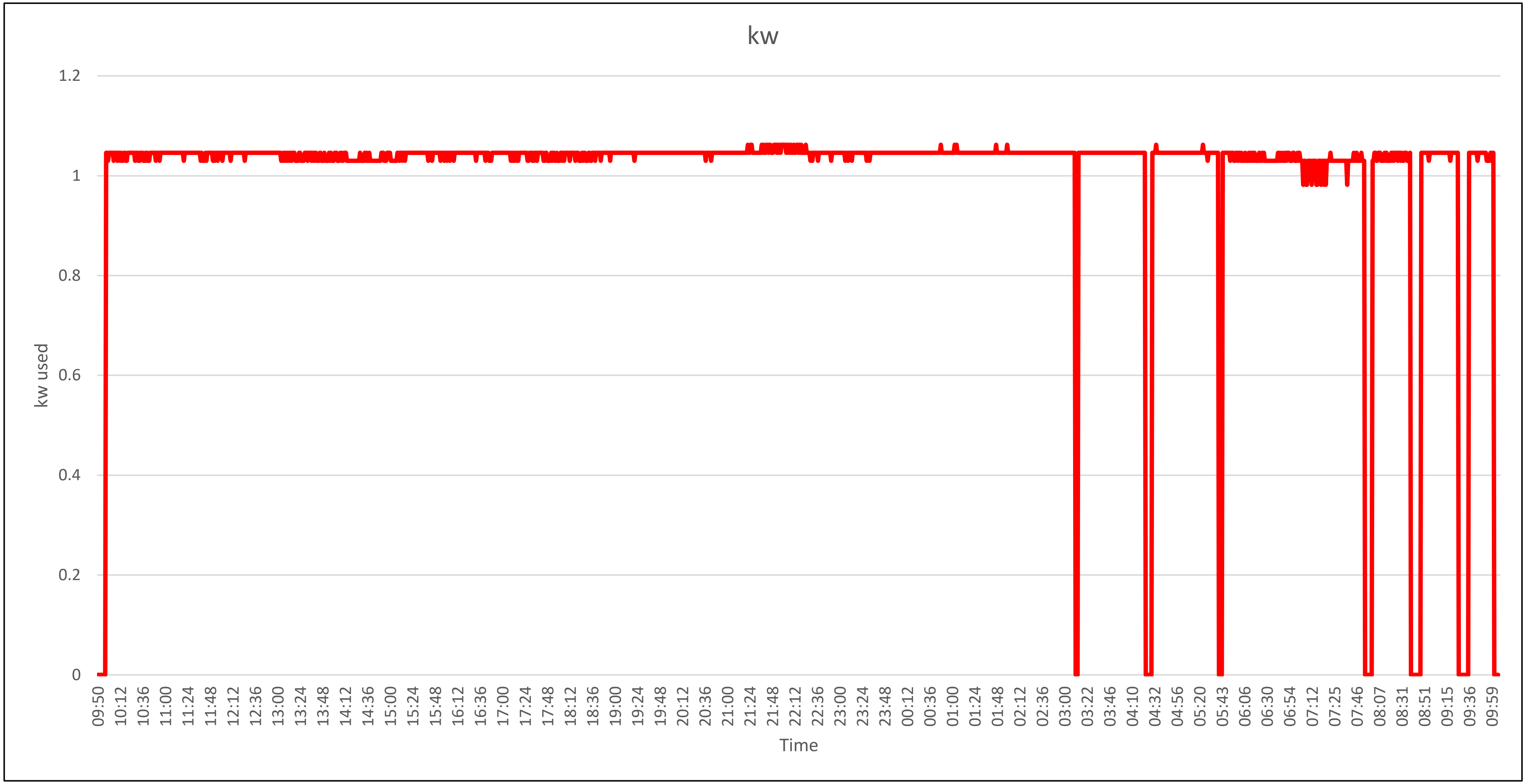


Figure 4 Electricity consumption- German Electric Radiator

Temperature:

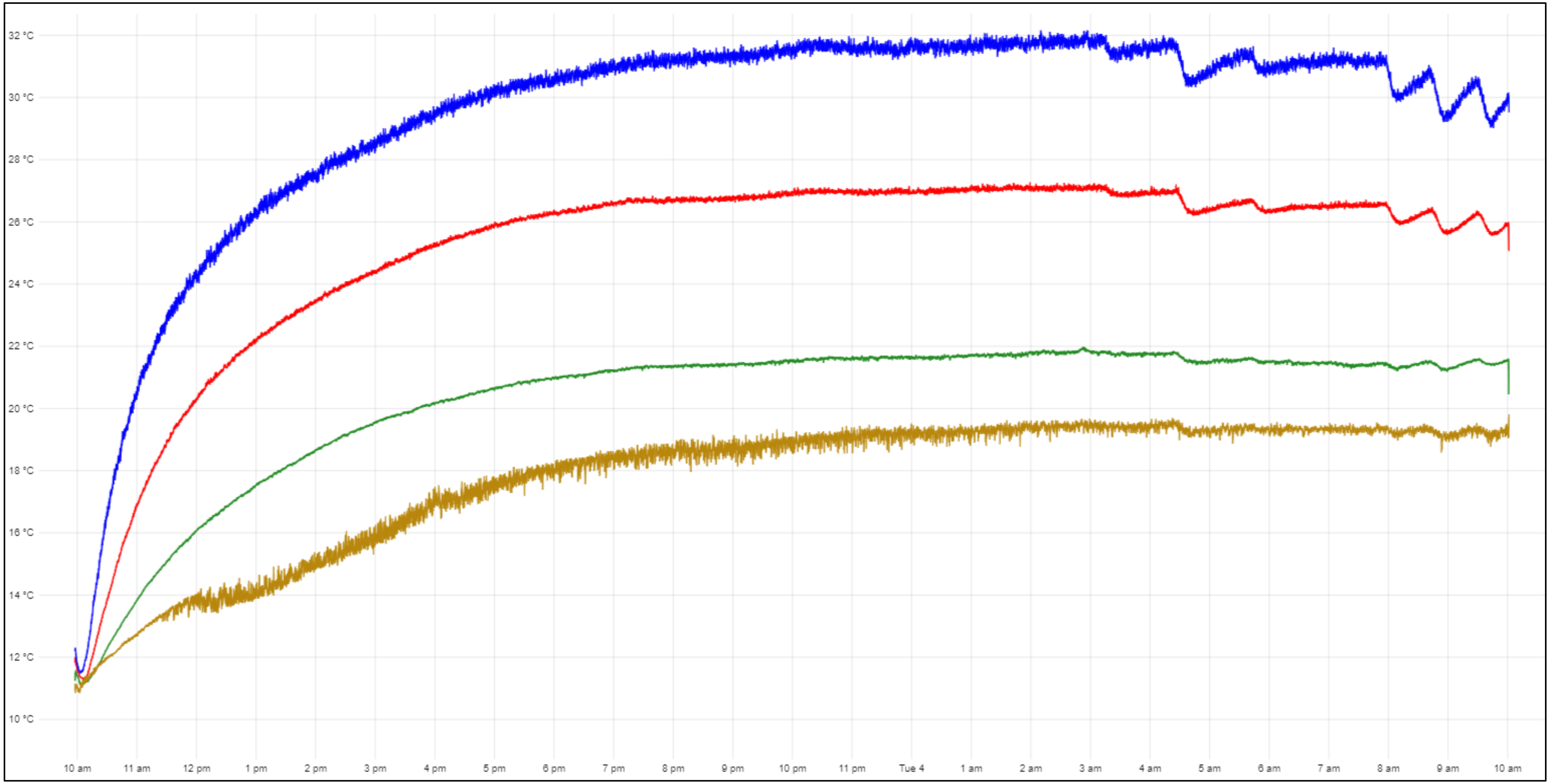


Figure 5 Room temperature- German Electric Radiator

A leading UK-German Electric Radiator:

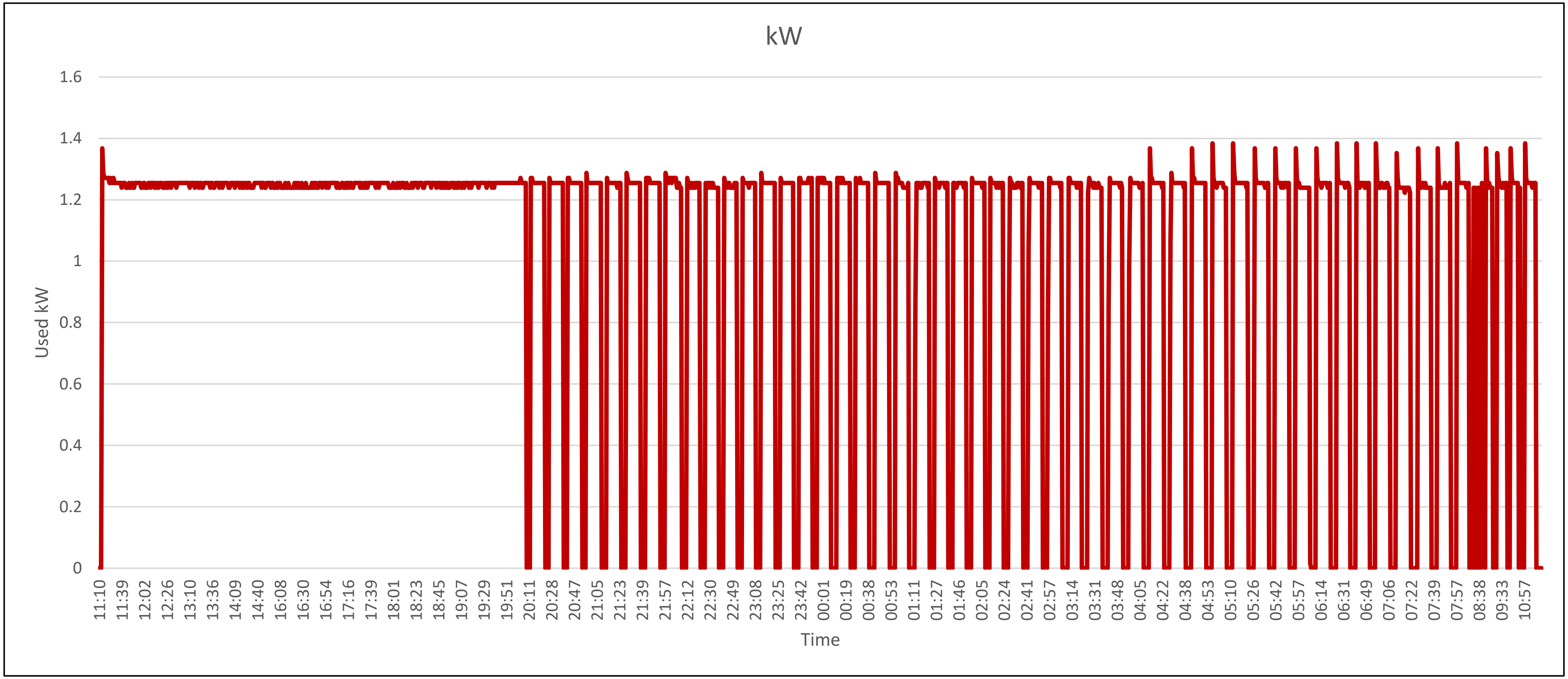


Figure 6 Electricity consumption- A leading UK-German Electric Radiator

Temperature:

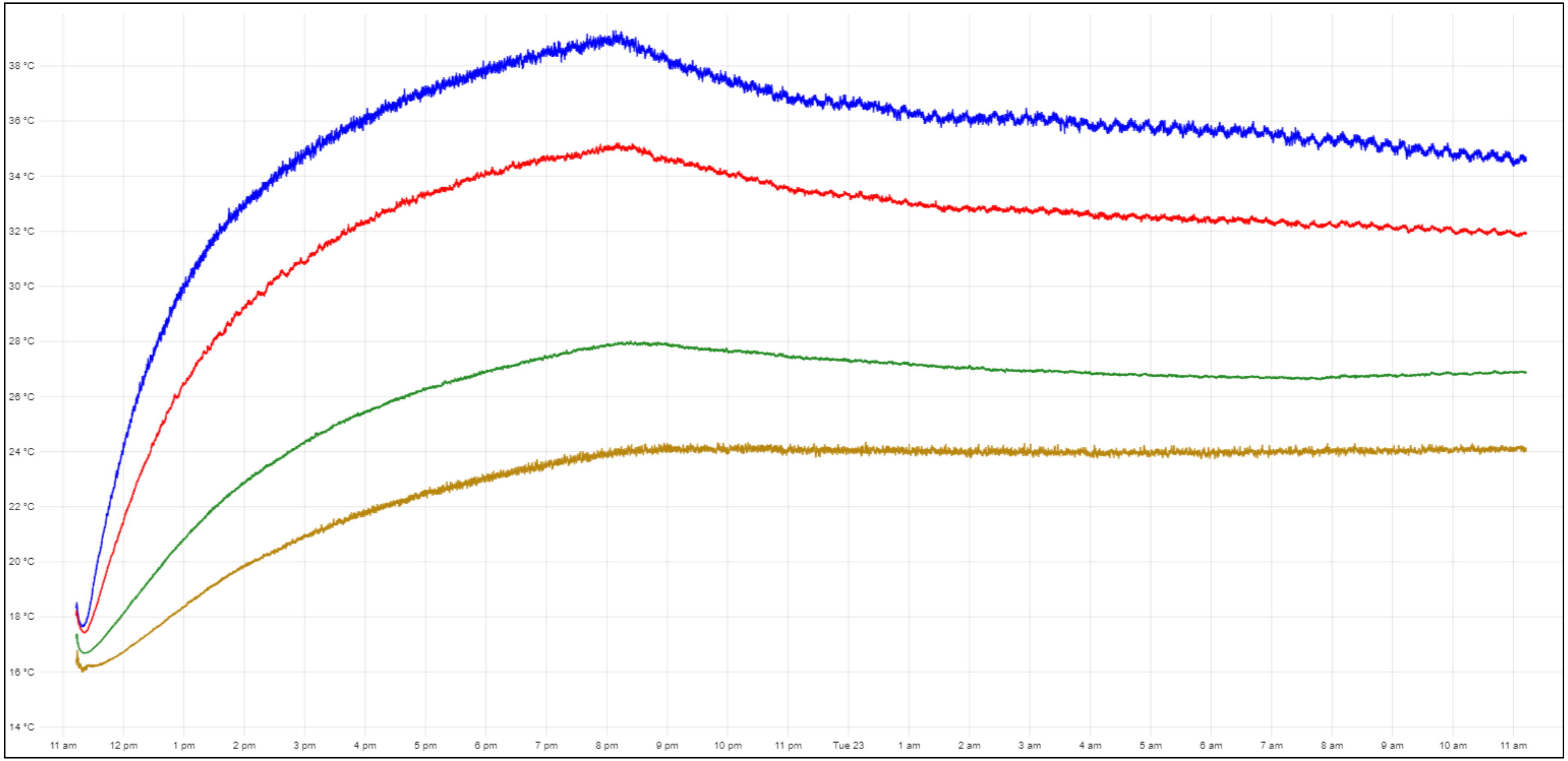


Figure 7 Room temperature - A leading UK-German Electric Radiator

Electric Panel Heater:

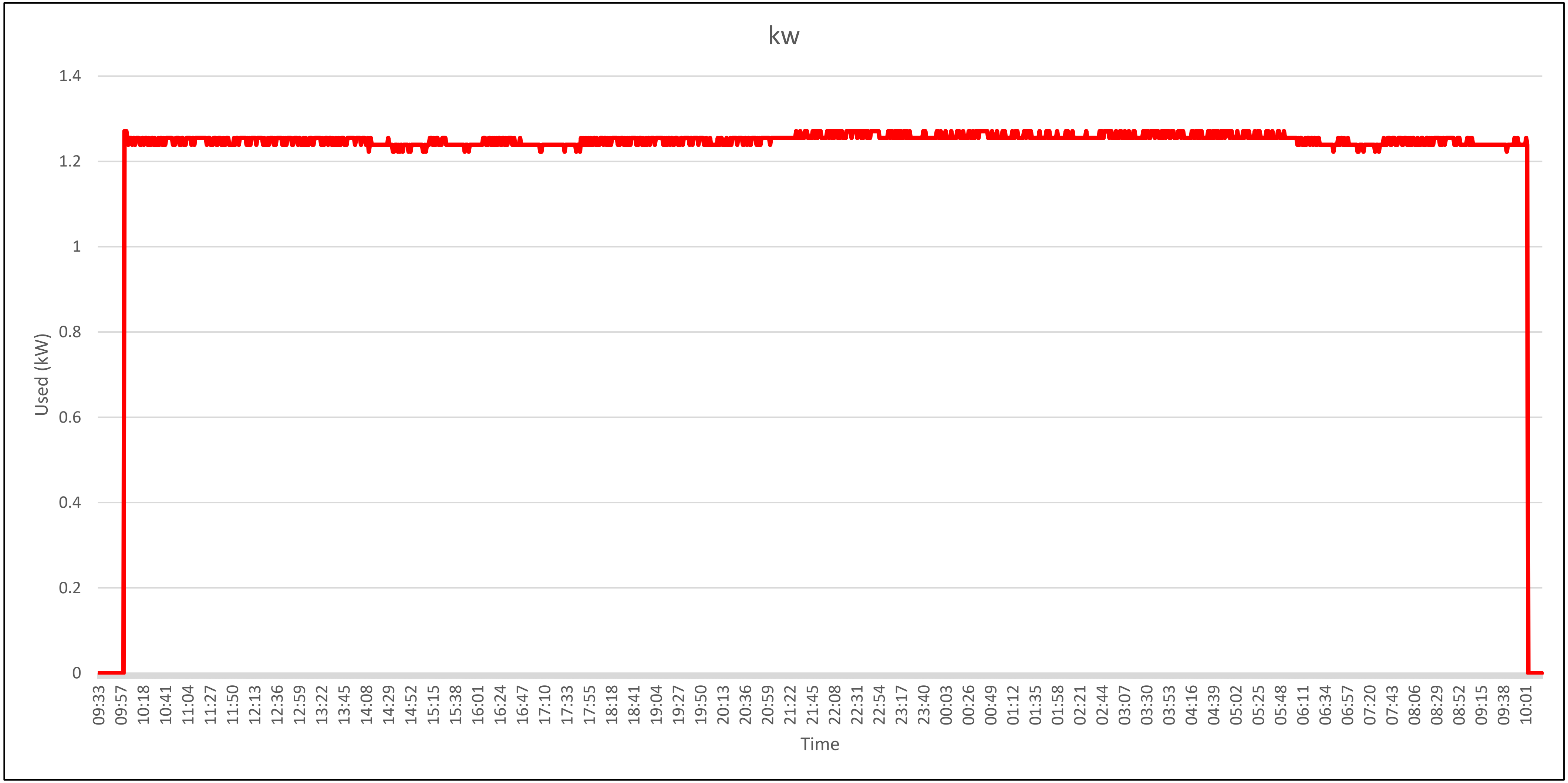


Figure 8 Electricity consumption- Electric Panel Heater

Temperature:

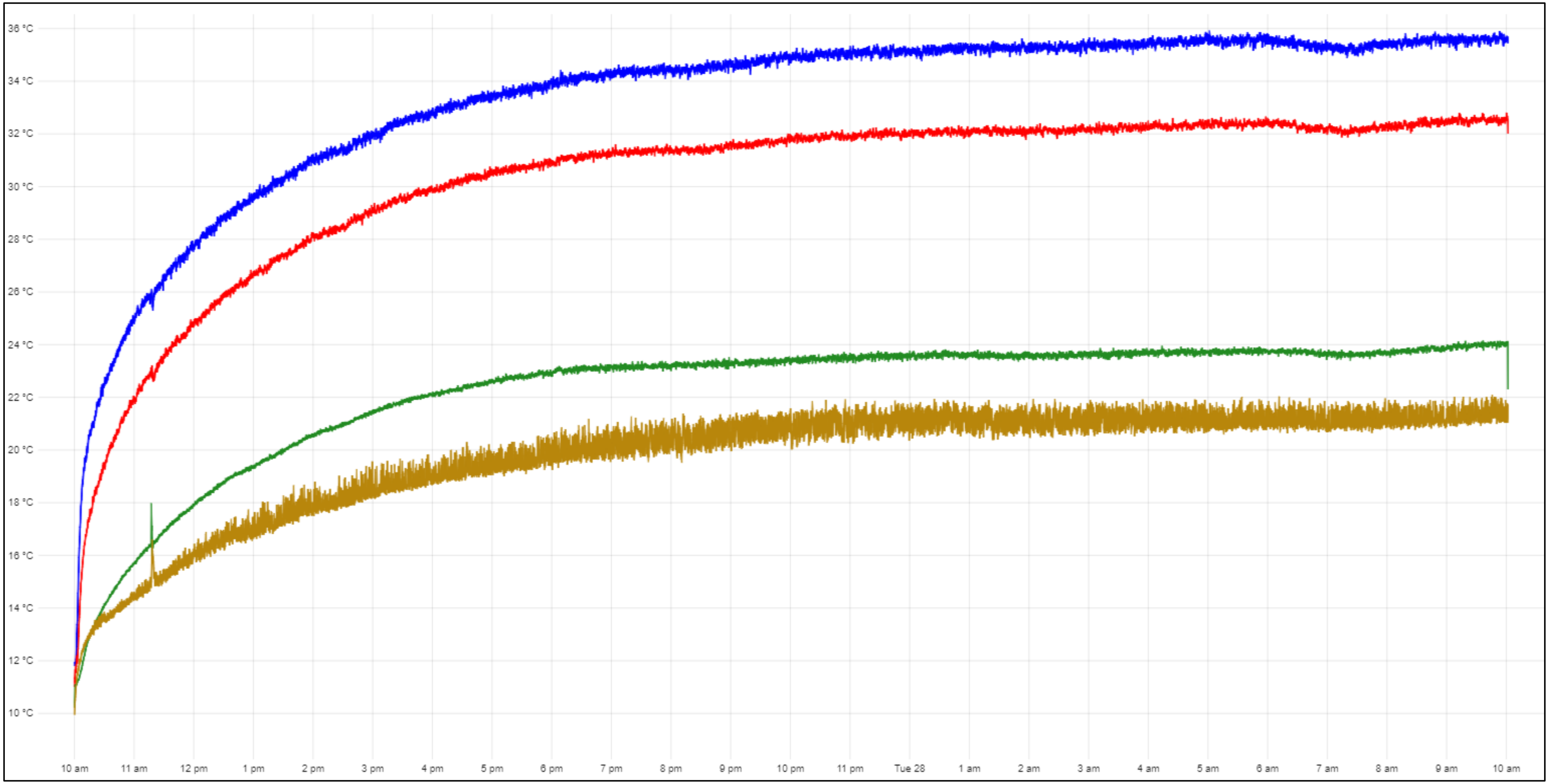


Figure 9 Room temperature- Electric Panel Heater

Oil Filled Panel Radiators

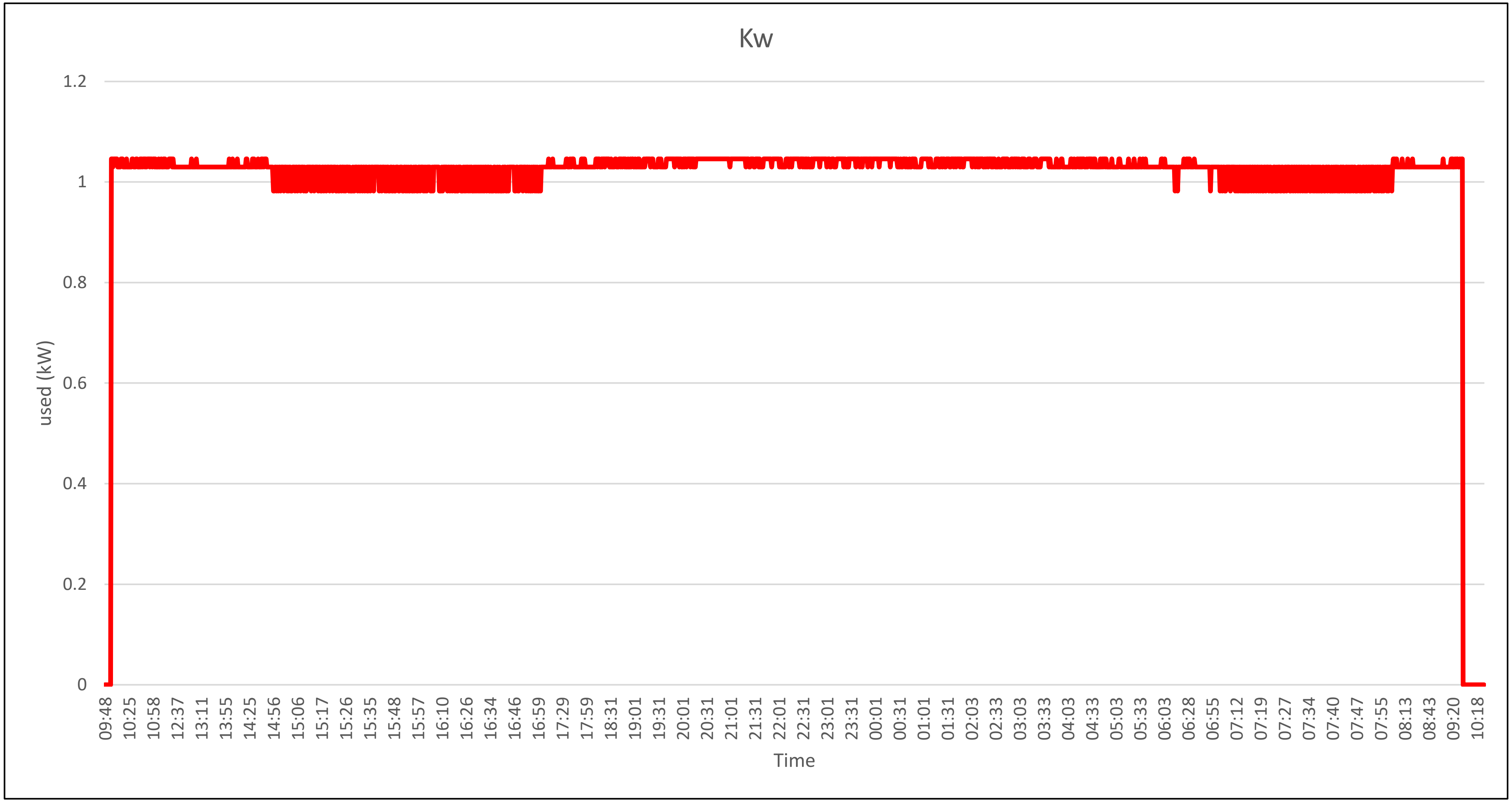


Figure 10 Electricity consumption - Oil Filled Panel Radiators

Temperature

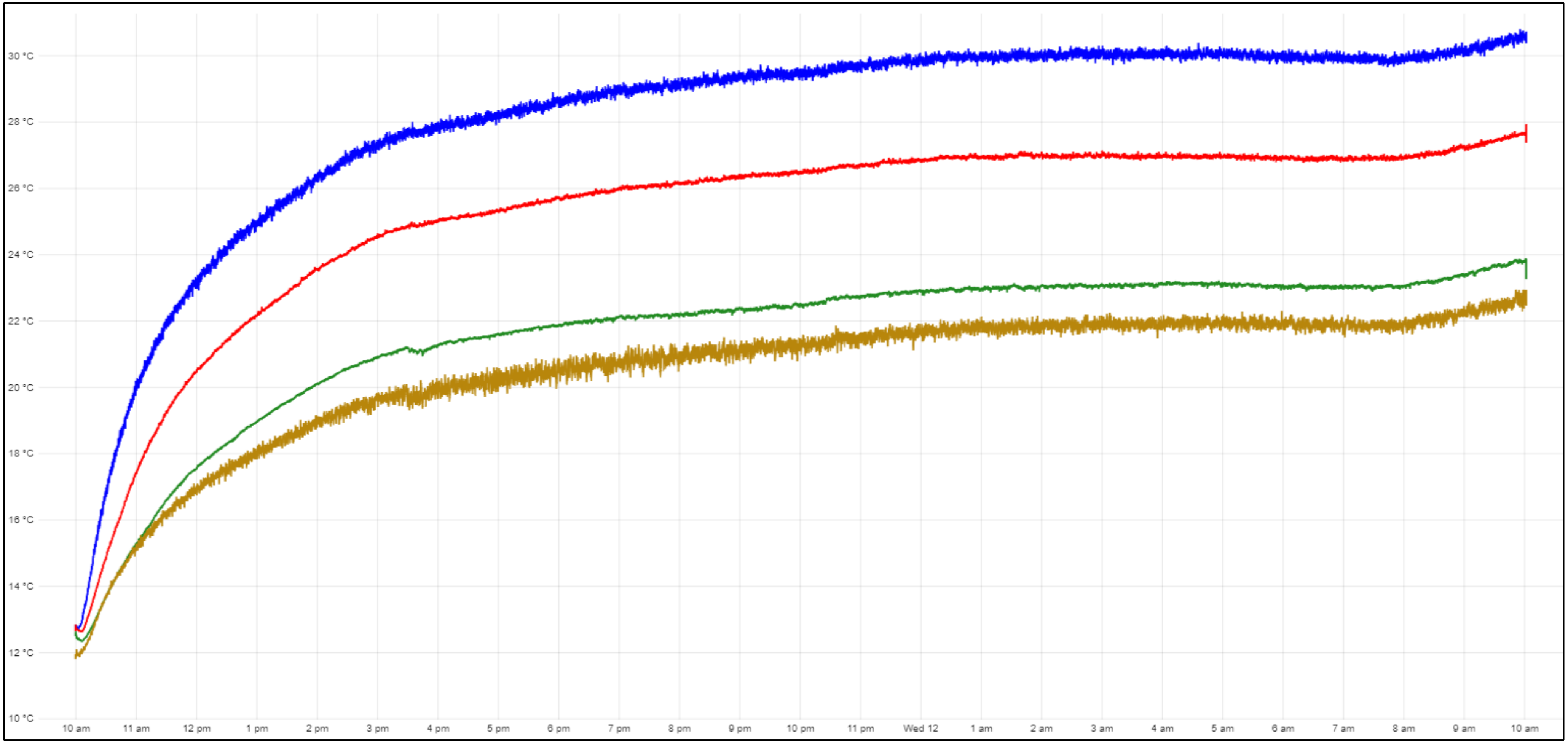


Figure 11 Room temperature - Oil Filled Panel Radiators

Comparison Table:

Company name / Size of radiator	Total Duration of test (Hrs)	Room temperature (Degree Celsius) (Start-End)	Humidity (%) (Start-End)	Duration of Radiator remained on (Hrs)	Duration Radiator remained off (Hrs)	Percentage of the time it remained off (%)	Total Energy Consumed (kwh)	Cost of running the radiator * based on 1khw cost 30p
Trust Electric Radiator (1.2 kW)	24 hrs	15°C to 22°C	59 % to 41 %	10 hrs 17 mins	13 hrs 43 mins	57.15 %	12.20 kwh	3.66 pounds
German Electric Radiator (1.1kW)	24 Hours	16°C to 23°C	57 % to 37 %	23 hrs 28 mins	0 hrs 32 mins	2.2 %	24.42 kwh	7. 3 pounds
Leading UK-German Electric Radiator (1.2kW)	24 Hours	16.5°C to 30.5°C	55 % to 39 %	20 hrs 2mins	3 hrs 58 mins	16.5 %	24.39 kwh	7.3 pounds
Electric Panel Heater (1.2 kW)	24 Hours	11°C to 24°C	53 % to 29 %	24hrs	0 hrs	0 %	30.09 kwh	9 pounds
Oil Filled Panel Radiators (1 kW)	24 Hours	10°C to 25°C	54 % to 38 %	24 hrs	0 hrs	0%	24.86 kwh	7.4 pounds

Discussion 1: Electricity Consumption

The findings from the 24-hour test period, as presented in Table 1, reveal that the Trust Electric Radiator exhibited superior performance in various domains, positioning it as the preferred choice for energy-efficient and cost-effective heating under this test conditions.

Energy consumption is a critical factor when evaluating radiator efficiency. The Trust Electric Radiator consumed 12.20 kWh during test period, whereas the other radiators consumed considerably higher amounts of energy, such as German electric radiator, leading UK-German electric radiator and oil filled panel radiator consumed 24.42 kWh, 24.39 kWh, 24.86 kWh respectively. While the electric panel heater consumed the highest energy that amounts to 30.09 kWh. This highlights the Trust Electric Radiator's ability to deliver efficient and economical heating, minimizing energy wastage.

Another significant aspect of radiator performance is the duration of time the radiator remains off. The Trust Electric Radiator remained off for 10 hours and 17 minutes, accounting for 57.15% of the total test period, indicating its ability to maintain room temperature effectively without constant energy consumption. In contrast, the other radiators remained on for longer durations, with German electric radiator being running for 23 hours and 28 minutes (97.8% of the test period), leading UK-German electric radiator for 20 hrs 2mins (83.46 %of the test period), while both of electric panel heater and the oil filled panel radiator constantly consumed energy for 24 hours (100% of the test period). This indicates that the Trust Electric Radiator has better control over maintaining room temperature and minimizing unnecessary energy usage during idle periods.

In terms of cost, the Trust Electric Radiator also emerged as the most cost-effective option. Based on a cost of 30 pence per kWh, the Trust Electric Radiator incurred a running cost of 3.66 pounds during the 24-hour test period, while German Electric Radiator and leading UK-German Electric Radiator incurred 7.3 pounds. The reason why both the German Electric Radiator and the leading UK-German Electric Radiator incur the same operating cost of 7.3 pounds, despite their difference in time duration the radiator was ON, can be attributed to the similarity in their overall energy usage. This similarity in energy consumption can be attributed to difference in their rating. The German electric radiator is 1.1 kw while on the other hand, the leading UK-German Electric Radiator has got rating of 1.2 kw. These small variations in energy consumption compensate for the differences in operating time, resulting in the same overall operating cost of 7.3 pounds for both radiators. Electric panel heater incurred 9 pounds, and oil filled panel radiators incurred 7.4 pounds. This further highlights the Trust Electric Radiator's cost-efficiency and potential for long-term energy savings.

Furthermore, the Trust Electric Radiator performed well in terms of room temperature and humidity. It effectively raised the room temperature from 15 °C to 22 °C during the test period, with humidity levels ranging from 59% to 41%. This indicates its ability to create a comfortable and conducive living environment.

Overall, based on the comprehensive analysis of the test data, the Trust Electric Radiator stands out as the clear winner in terms of energy consumption, idle time, cost-effectiveness, and performance in maintaining room temperature and humidity. It showcases superior operational characteristics, making it the preferred choice for consumers seeking an energy-efficient and cost-effective heating solution.

Discussion 2: Surges and Spikes?

Upon careful examination of the data, including electricity consumption from the graphs for all the radiators, it has been observed that the Trust radiator is consuming electricity within the tolerance range specified. However, the leading UK-German electric radiator, as shown in Figure 12, exhibits spikes in electricity consumption, reaching values of around 1.4 kW, which exceeds its specified rating of 1.2 kW by around 200 watts. This indicates that the leading UK-German electric radiator is pulling more energy than its designated rating, resulting in potential overloading of the electrical circuit and posing a risk.

It is worth noting that unlike devices such as washing machines, where users are typically aware of the varying energy consumption levels during different cycles, radiators are often perceived to consume energy based on their specified ratings. However, the presence of spikes in electricity consumption, as evident in Figure 12, may not be readily apparent to users unless they use a meter to monitor energy usage. This not only results in higher energy consumption than expected but can also be hazardous as it affects the overall amperage of the house, potentially leading to electrical circuit failures.

These findings highlight the importance of accurately measuring and monitoring the energy consumption of radiators, it is crucial for consumers to be aware of potential spikes in energy consumption and their implications to make informed decisions about radiator usage and minimize potential risks.

Furthermore, the presence of spikes in electricity consumption, as observed in the leading UK-German electric radiator, may also be indicative of potential issues with the quality and safety of the radiator. Radiators that exhibit such irregular energy consumption patterns may indicate poor manufacturing or components, which could compromise their performance, durability, and safety over time. This underscores the importance of thoroughly evaluating radiators based on safety and quality parameters, in addition to energy efficiency and heat output, when making purchasing decisions. Consumers should be vigilant in researching and selecting radiators from reputable manufacturers that adhere to industry standards and regulations to ensure they are investing in a safe and reliable heating solution for their homes or establishments.

It is crucial for consumers to prioritize not only the energy efficiency and heat output of radiators, but also factors such as reliability, durability, and adherence to safety standards. Considering the long-term implications of radiator performance, energy consumption, and potential impacts on electrical systems, it is essential to thoroughly evaluate the quality and safety parameters of radiators before making a purchase decision.

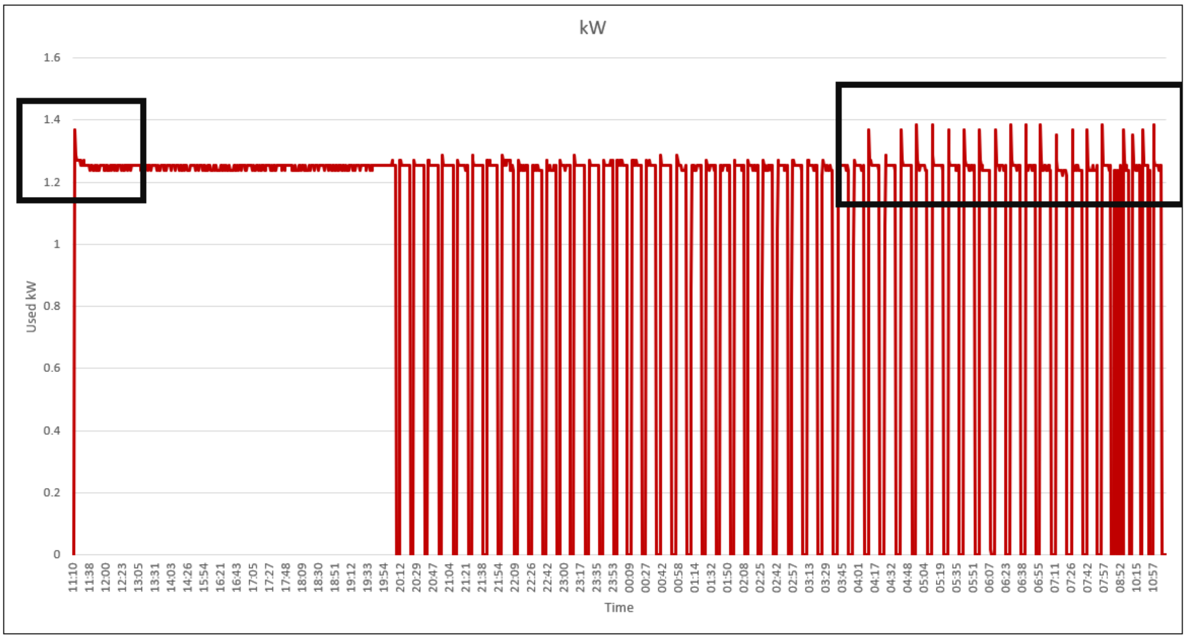


Figure 12 Highlighted spikes of leading UK-German Electric Radiator.

Discussion 3: Temperature graphs

	Trust	German Electric Radiator	leading UK-German Electric Radiator	Oil Filled Panel Radiators	Electric Panel Heater
Average Top Temperature	26 °C	32 °C	34 °C	30 °C	35 °C
Average Middle temperature	23 °C	27 °C	28 °C	27 °C	32 °C
Average Bottom Temperature	20 °C	21 °C	23 °C	22 °C	23 °C
Time to reach to highest temperature in room	2 hrs	10 hrs	7 hrs	12 hrs	12 hrs

Based on the temperature data obtained from the test, it can be observed that the Trust Electric Radiator had an average top temperature of 26 °C, middle temperature of 23 °C, and bottom temperature of 20 °C. In comparison, the German electric radiator had the highest temperatures with 32 °C at the top, 27 °C in the middle, and 21 °C at the bottom. The leading UK-German electric radiator had similar temperatures to the German electric radiator with

34 °C at the top, 28 °C in the middle, and 23 °C at the bottom. The oil filled panel radiator had slightly lower temperatures with 30 °C at the top, 27 °C in the middle, and 22 °C at the bottom. The electric panel heater had the highest temperature at the top and middle with 35 °C and 32 °C, and 23 °C at the bottom side, respectively.

The time taken by each radiator to reach the highest temperature in the room was also recorded during the test. The Trust Electric Radiator took just 2 hours to reach the highest temperature, which was the shortest among all the radiators. The German electric radiator took 10 hours, followed by the leading UK-German electric radiator with 7 hours, and both the oil filled panel and electric panel heater took 12 hours each.

These findings suggest that the Trust Electric Radiator was able to heat the room relatively faster compared to the other radiators, reaching a comfortable temperature level within 2 hours. On the other hand, competitor's radiators were not even near, indicating potential limitations in their performance.

It is worth noting that the temperature distribution in the room can have a significant impact on the overall comfort and efficiency of a radiator. The Trust Electric Radiator demonstrated relatively consistent temperature distribution across the top, middle, and bottom levels, indicating effective heat distribution with the difference between top and bottom side being just 6 °C. In contrast, other radiators showed higher temperature differences between the top and bottom levels, this difference was more than 10 °C. Conditions such as these may result in uneven heating and discomfort for occupants. A radiator with a smaller temperature difference between the top and bottom sides generally indicates more uniform heat distribution, which can result in a more comfortable and evenly heated room.

Based on physics, there could be several potential reasons for a high temperature difference between the bottom and top sides of the room while a radiator is in use. The design and construction of the radiator can also impact the distribution of heat.

There are other various factors as well that could influence the room heating distribution like insufficient insulation, heat source placement, structural factors such as the design and construction of the room. For example, rooms with high ceilings or large windows may experience greater temperature differences between the upper and lower areas. To control this, all experiments were carried keeping all these influencing factors as uniform.

Discussion 4: Temperature – Initial period heating of room

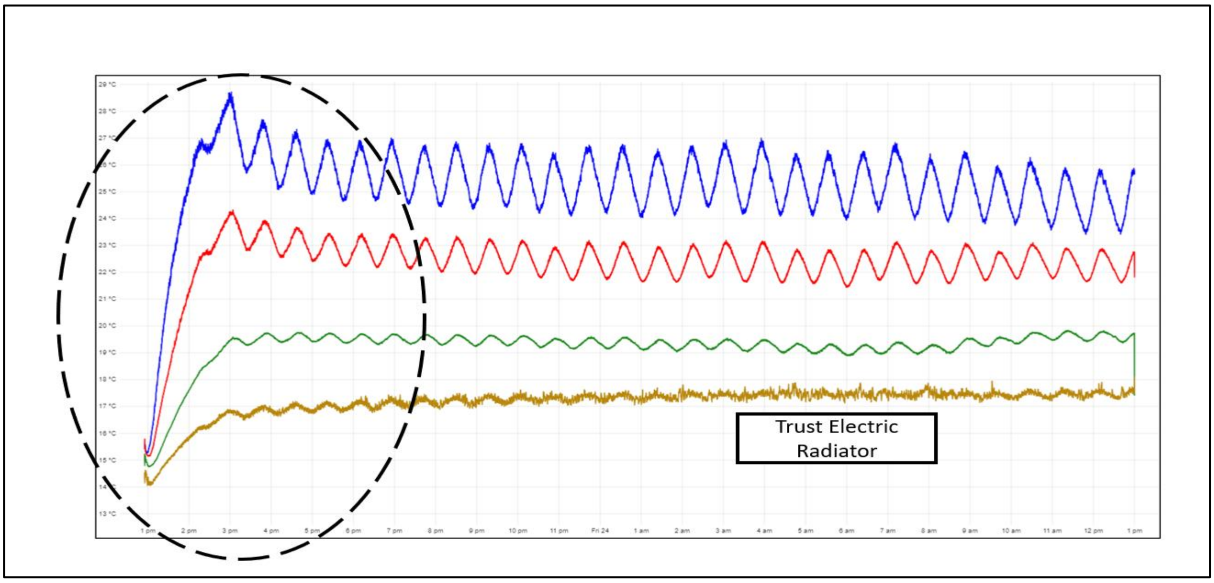


Figure 13 Highlighting initial stage of Trust Electric Radiator

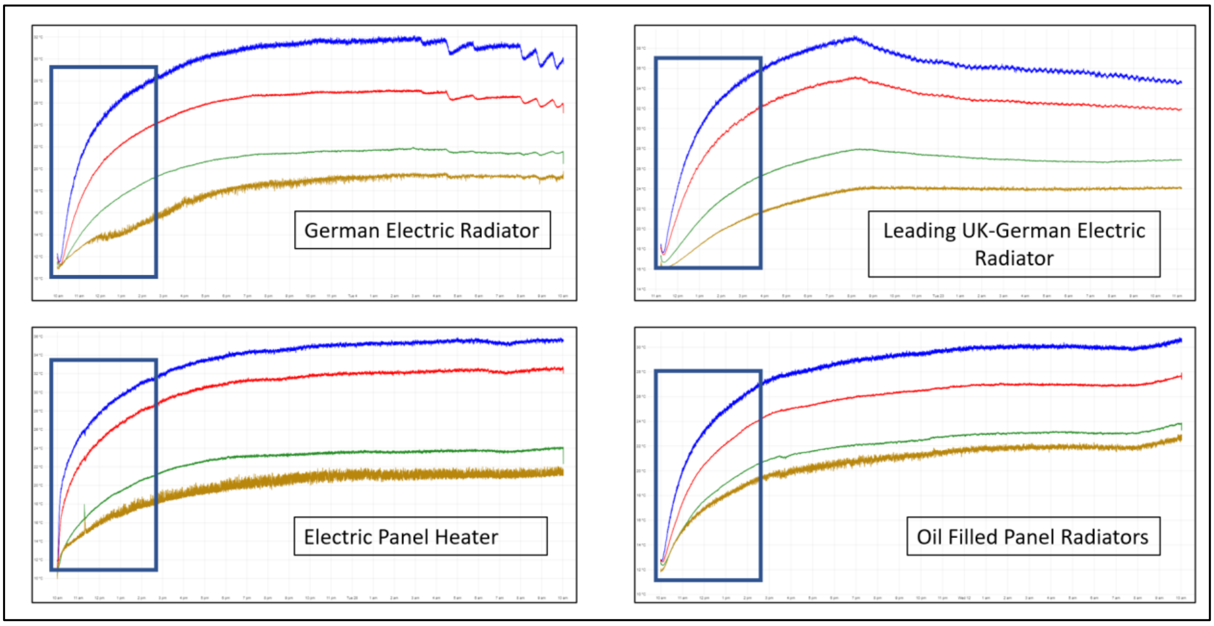


Figure 14 Comparing four competitors for initial period.

Based on the comparison of the graphs (figure 13 and 14) showing the room temperature at three different levels (bottom, mid, top) over a period (e.g., first 2 hours), it appears that the slope of the line representing the Trust radiator is steeper compared to the other radiators. This suggests that the Trust radiator heats up the room more quickly than the other radiators during the initial period, resulting in a faster rate of temperature increase.

FAQs

The running costs if all radiators were 1 kW

	Trust Electric Radiator	German Electric Radiator	Leading UK-German Electric Radiator (1.2kW)	Electric Panel Heater	Oil Filled Panel Radiators
Original Rating	1200 watt	1100 watt	1200 watt	1200 watt	1000 watt
Energy Consumed with specified rating	12.20 kwh	24.42 kwh	24.39 kwh	30.09 kwh	24.86 kwh
Assumed rating	1000 watt	1000 watt	1000 watt	1000 watt	1000 watt
Percentage decrease in rating	16.67	9.09	16.67	16.67	0

If assumed that all radiators have rating of 1 kW, then their energy consumption will be affected and based on the calculations above, their energy consumption can be predicted as following:

	Trust Electric Radiator	German Electric Radiator	Leading UK-German Electric Radiator (1.2kW)	Electric Panel Heater	Oil Filled Panel Radiators
Energy Consumed	10.17	22.20	20.32	25.07	24.86
Cost of running the radiator * based on 1khw cost 30p	£ 3.05	£ 6.66	£ 6.09	£ 7.52	£ 7.45

The warmup time of the room for each radiator

We can determine the time it takes for the room to reach a temperature of 20°C (a good value to consider the room is warm). For consistency, we can use the value of the thermocouple located at waist height, which is in the middle of the room. This height is also commonly used by consumers to measure room temperatures in their homes since most of the temperature controllers are found around this height, making it a suitable reference point for determining the average room temperature.

	Trust Electric Radiator	German Electric Radiator	Leading UK-German Electric Radiator (1.2kW)	Oil Filled Panel Radiators	Electric Panel Heater
Time to reach 20 °C	50 minutes	55 minutes	55 minutes	34 minutes	1 hour 47 minutes

Reasons why each radiator performed as it did?

When it comes to understanding why each radiator performed as it did, it's important to take a closer look at the physical properties of the materials that the radiator is made of. By doing so, we can gain a better understanding of how these properties impact the radiator's performance.

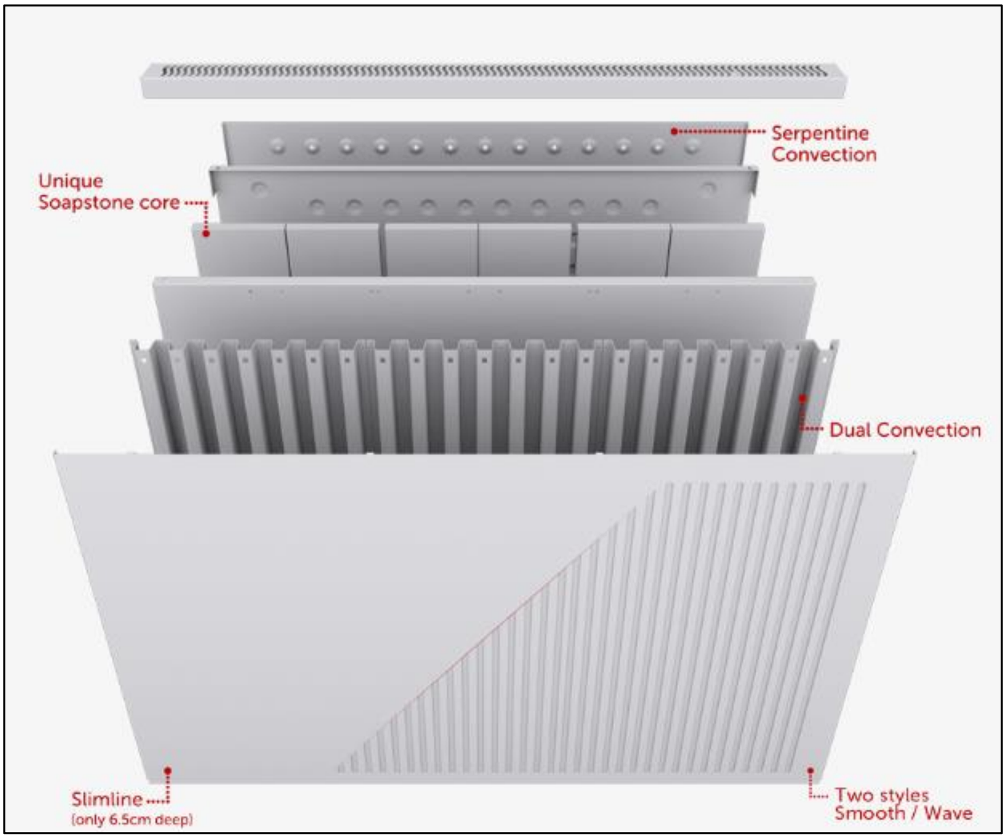
First, let's consider specific heat capacity which is a measure of the amount of heat energy required to raise the temperature of a material by one degree Celsius or one Kelvin. It is often expressed as joules per gram per degree Kelvin.
Different materials have different specific heat values, which can affect how they respond to changes in temperature. Materials with high specific heat values require more energy to increase their temperature while those with low specific heat values require less energy to increase their temperature.
Next, let's look at thermal conductivity. This property refers to a material's ability to conduct/transfer heat and has the SI units of W/m·K (Watts per meter-Kelvin). Radiators made of materials with high thermal conductivity, such as aluminium, will transfer heat more quickly than radiators made of materials with lower thermal conductivity. This means that aluminium radiators, will heat up room more quickly than other types of radiators as a high thermal conductivity material allows heat to flow through it easily, while a low thermal conductivity material resists the flow of heat.

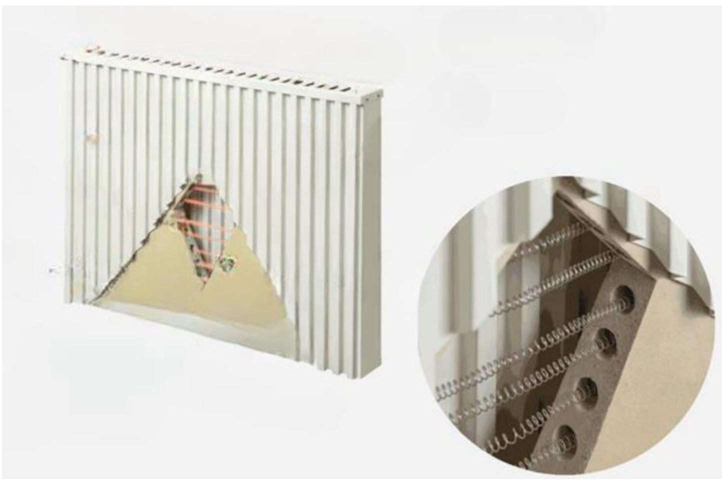
Density is another important property to consider. This property refers to the mass per unit volume of a material. Radiators made of denser materials, will hold more heat energy, and release it over a longer period than radiators made of less dense materials. This is because denser materials are better at storing and releasing heat.

By taking these properties into consideration, we can gain a better understanding of why each radiator performed as it did. The secret of efficient heating is to distribute each kW of heat into the room quickly, and most importantly, the better the distribution, the more efficient and effective the radiator will be.

Brand	Property values
Trust Electric Radiator 1.2 KW	<u>Soapstone:</u> Specific heat capacity: 0.98 *KJ/KgK* Thermal conductivity: 6.4 *W/mK* Density: 2,980 *kg/m³*

	Aluminium: Specific heat capacity: 0.896 *KJ/KgK* Thermal conductivity: 159 *W/mK* Density: 2750 *kg/m3*
German Electric Radiator (1.1kW)	Chamotte core: Specific heat capacity: 1 *kJ/kgK* Thermal conductivity: *1.4 W/mK* Density: 667 *kg/m3* Steel: Specific heat capacity: 0.510 *KJ/KgK* Thermal conductivity: 45 *W/mK* Density:7500 *Kg/m3*
Leading UK-German Electric Radiator 1.25 KW	Chamotte core: Specific heat capacity: 1 *kJ/kg*K* Thermal conductivity: *1.4 W/m*K* Density: 667 *kg/m3* Steel: Specific heat capacity: 0.510 *KJ/KgK* Thermal conductivity: 45 *W/mK* Density:7500 *Kg/m3*
Electric Panel Heater 1.2 KW	Heating element + Steel casing Specific heat capacity: 0.510 *KJ/KgK* Thermal conductivity: 45 *W/mK* Density: 7500 *Kg/m3*
Oil Filled Panel Radiators 1KW	Diathermic oil Specific heat capacity: 2.0 - 2.5 *kJ/kg·K.* Thermal conductivity: 0.1 - 0.15 *W/(m·K)* Density: 700 - 900 kg/m^3 * Values are only typical and can vary depending on the specific type and grade of diathermic oil being used. Steel casing Specific heat capacity: 0.510 *KJ/KgK* Thermal conductivity: 45 *W/mK* Density: 7500 *Kg/m3*

Brand	Reason for main performances
Trust Electric Radiator 1.2 KW	Reason for lower operating cost: Soapstone has long been known for its ability to retain heat as having the much higher value for density as compared to stone used by competitors. Also, with the lowest specific heat capacity and higher thermal conductivity, it takes less time to heat up and transfer this heat quickly. Quick warmup time and homogenous room temperature: Aluminium is one of the most widely used materials in the world, and for a good reason. Not only is it lightweight, durable, and relatively inexpensive to produce, but it is also an incredibly efficient conductor of heat. Aluminium is an excellent heat conductor because it possesses a high thermal conductivity, allowing it to transfer heat quickly and efficiently from one object to another. Combination of these two materials along with optimized design of the casing allows it to maintain the room temperature in comfortable range at the lowest cost. 
German Electric Radiator (1.1kW)	The core of the radiator is made of chamotte—also known as ‘grog’, ‘firesand’ or “fireclay”—is calcined clay containing a high proportion of alumina. From the data, we could infer that specific heat capacity is slightly higher than the soapstone, which indicates that it would take more time to heat up than the stone when compared with soapstone as evident from the time taken for room to heat up to 20°C. Moreover, the energy consumed is also twice compared to Trust radiator, the reasons for which could be the following:

	Firstly, the thermal conductivity of chamotte core is less than the soapstone, which slows down the heat transfer to the steel casing when compared to transfer of heat from soapstone to aluminium case in case of trust. Further, the density of the chamotte is much lower, which effects its heat storage capacity and then the steel casing has much higher density which could store the heat, while the actual work of the casing is to effectively transfer the heat to room, this contrast in densities effects is convection rate as well could be another reason for high surface temperatures which are unsafe for humans particularly in cases where care is required. 
Leading UK-German Electric Radiator (1.2 KW)	This system has the 40mm Heat Core that is installed closer to front panel of radiator in comparison to 17mm core width of trust radiator. The company claims that the core can reach temperatures of 1500°C making it unsafe and prone to injuries as the core is very close to the front of radiator. Due to similar material of core as German electric radiator, it takes around similar time to warm up room initially and their energy consumption behaviour is also similar. 

Electric Panel Heater (1.2 KW)	This is a simple electric panel radiator that consists of electric heating element encased into steel body. The heating elements start to heat up as electricity passes through them. These elements are usually made of metal and have a high resistance to electricity, which causes them to become very hot. This is the reason for quick warm up. Further, the reason for the high energy consumption is evidenced from the fact that there is no storage element in the radiator which leads to continuous working of the heater and without reaching the desired temperature in the room, for which another reason could be its poor design. 
Oil Filled Panel Radiators (1KW)	Specific capacity value for the diathermic oil, that is heated by the elements is too high as compared to the stones. Also, the density of the oil is too less in value that could support in storing energy which directly effects the energy consumption of the radiator. 

Conclusion

In conclusion, based on the temperature data and time taken to reach the highest temperature in the room and the cost of operation, the Trust Electric Radiator outperformed the other radiators in terms of faster heating and relatively consistent temperature distribution across different levels in the room at the lowest cost. This suggests that the Trust Electric Radiator is more energy-efficient and effective option for maintaining comfortable room temperatures.

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